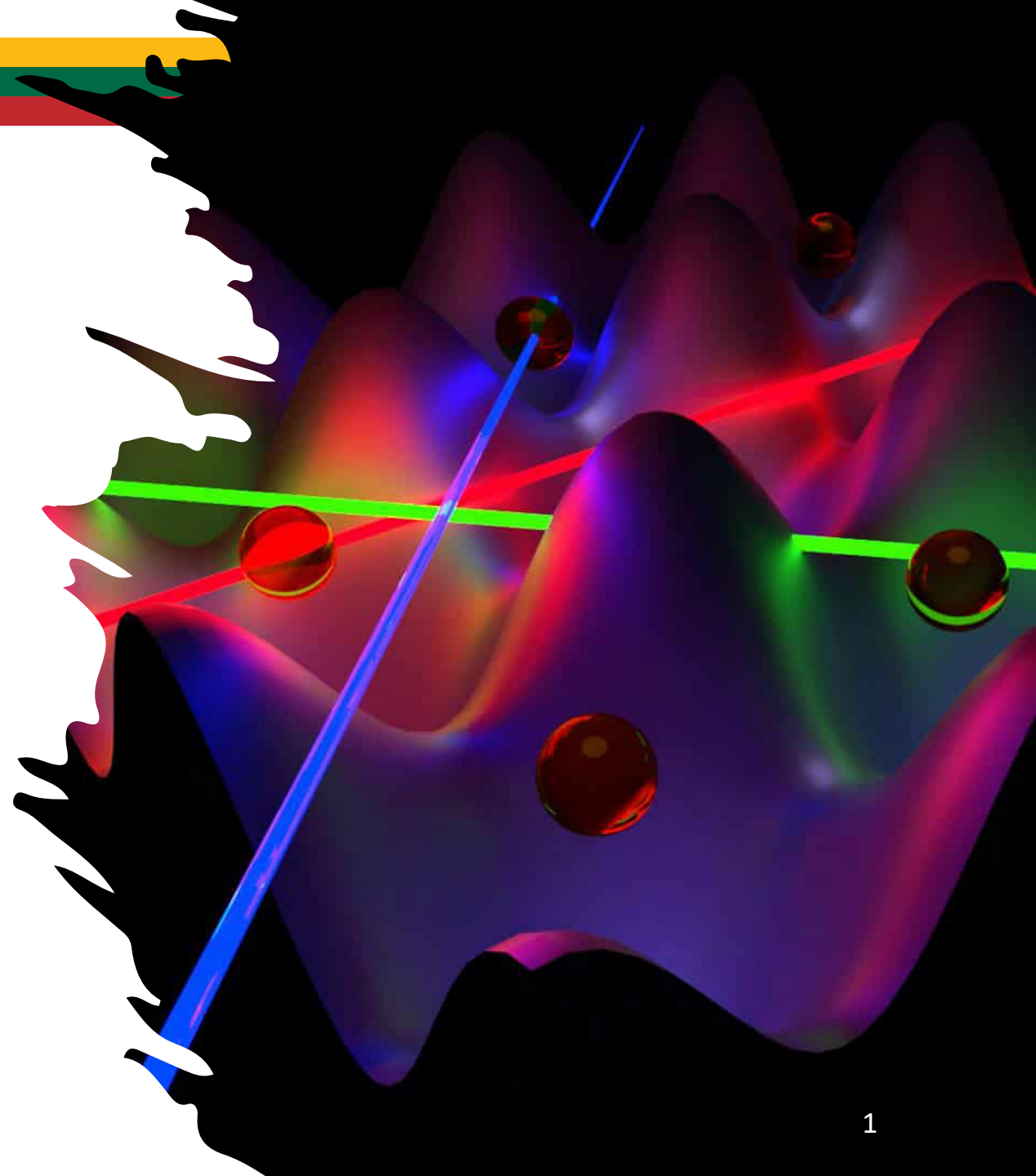# LITHUANIAN INTERNATIONAL QUANTUM COOPERATION AND INCENTIVES FOR COOPERATION

Gediminas Juzeliūnas, Lithuania

30 March 2023, Brussels

Vilnius University (Old Campus)

National Center for Physical Sciences and Technology

Vilnius University (Old Campus)

National Center for Physical Sciences and Technology

Quantum theoretical and experimental research in Lithuania - long traditions

Adolfas Jucys (Pioneer in Quantum Physics)

Quantum theoretical and experimental research in Lithuania - long traditions

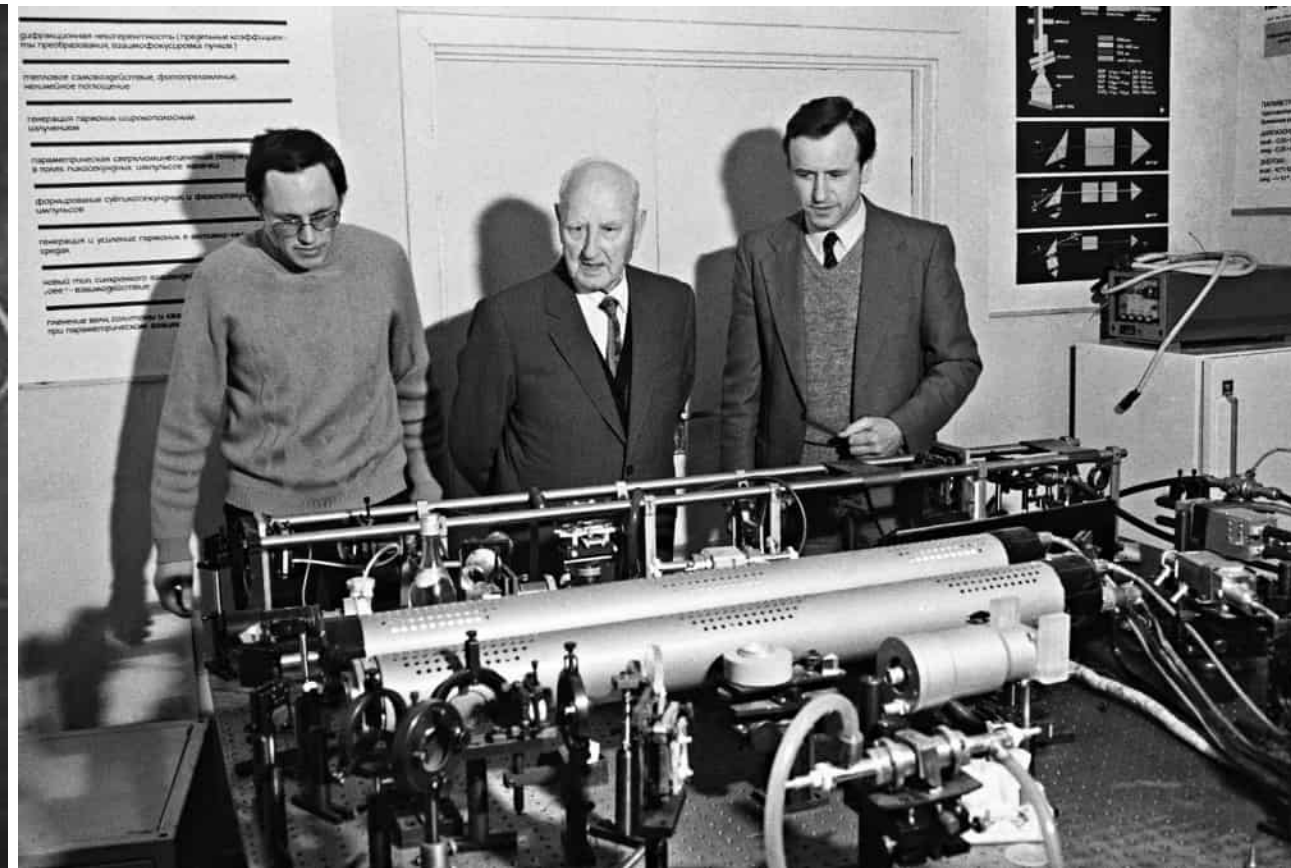
Adolfas Jucys (Pioneer in Quantum Physics)

- Currently theoretical physicists solve problems of modern quantum physics and quantum technology

Quantum theoretical and experimental research in Lithuania - long traditions

Adolfas Jucys (Pioneer in Quantum Physics)

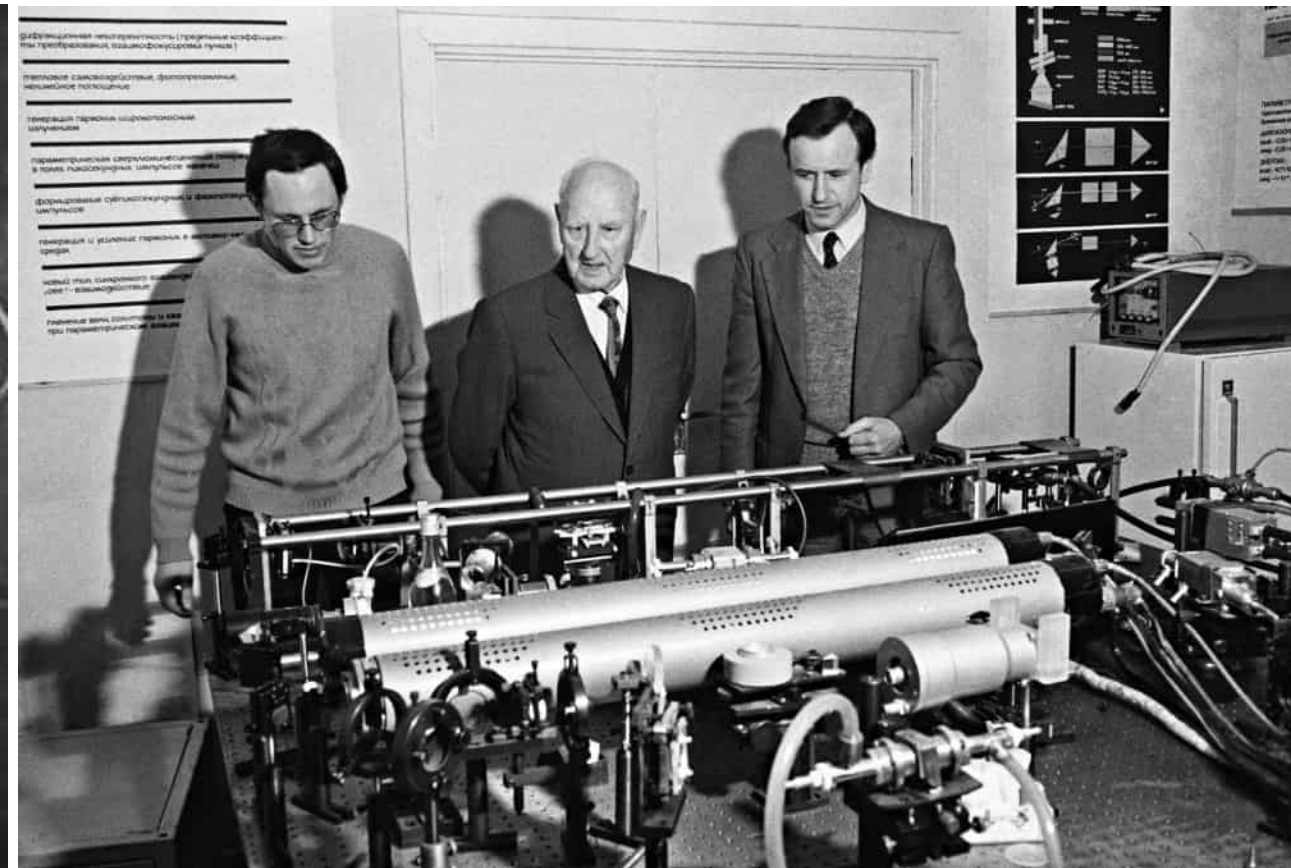R. Danielius, **P. Brazdžiūnas**, A. Piskarskas

- Currently theoretical physicists solve problems of modern quantum physics and quantum technology
- Current experimental studies: Laser & condensed matter physics, quantum technologies + more

Quantum theoretical and experimental research in Lithuania - long traditions

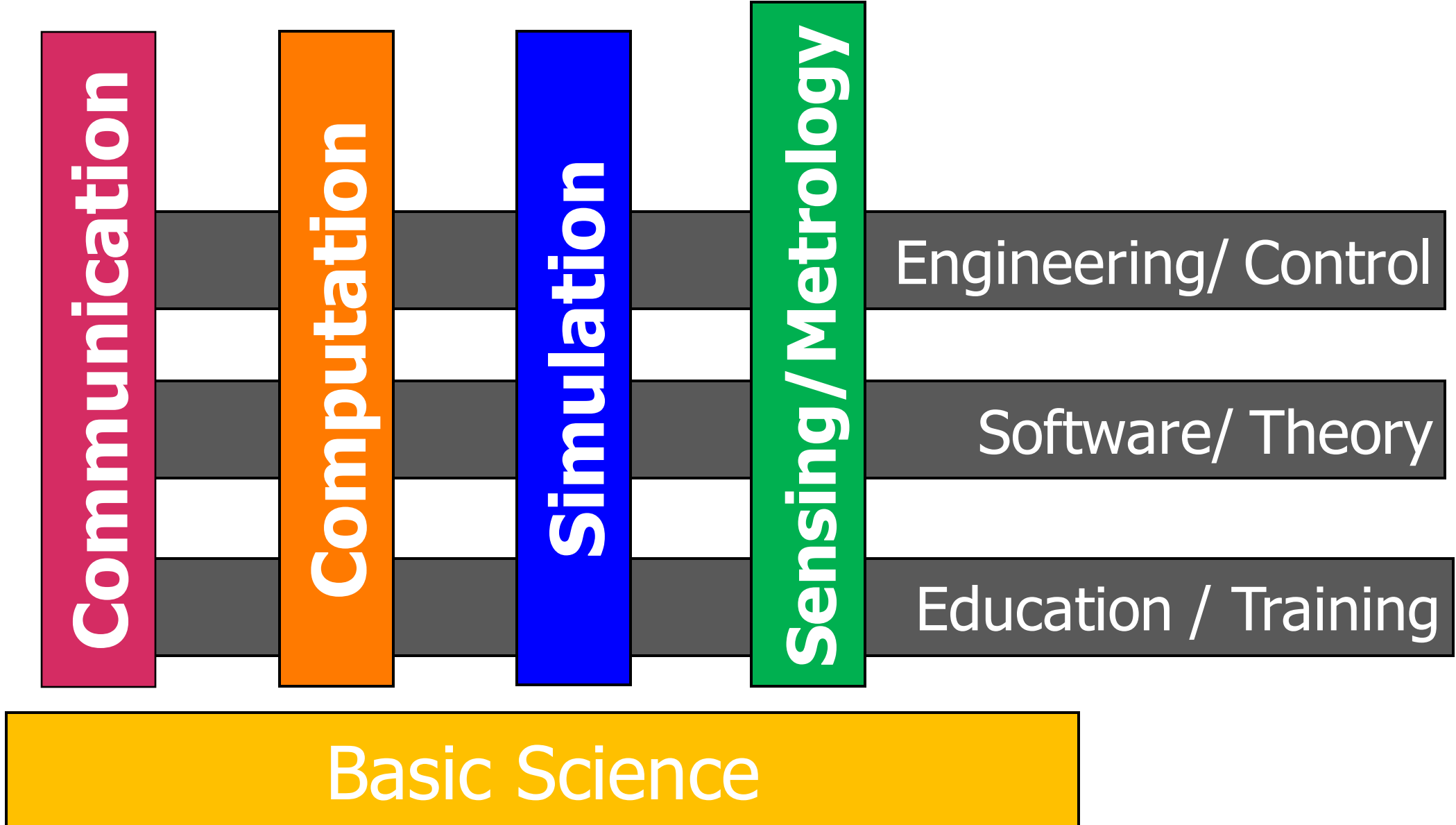
Adolfas Jucys (Pioneer in Quantum Physics)

R. Danielius, **P. Brazdžiūnas**, A. Piskarskas

- Currently theoretical physicists solve problems of modern quantum physics and quantum technology
- Current experimental studies: Laser & condensed matter physics, quantum technologies + more

Lithuanians are working in all <u>four pillars </u>of the Quantum Technologies

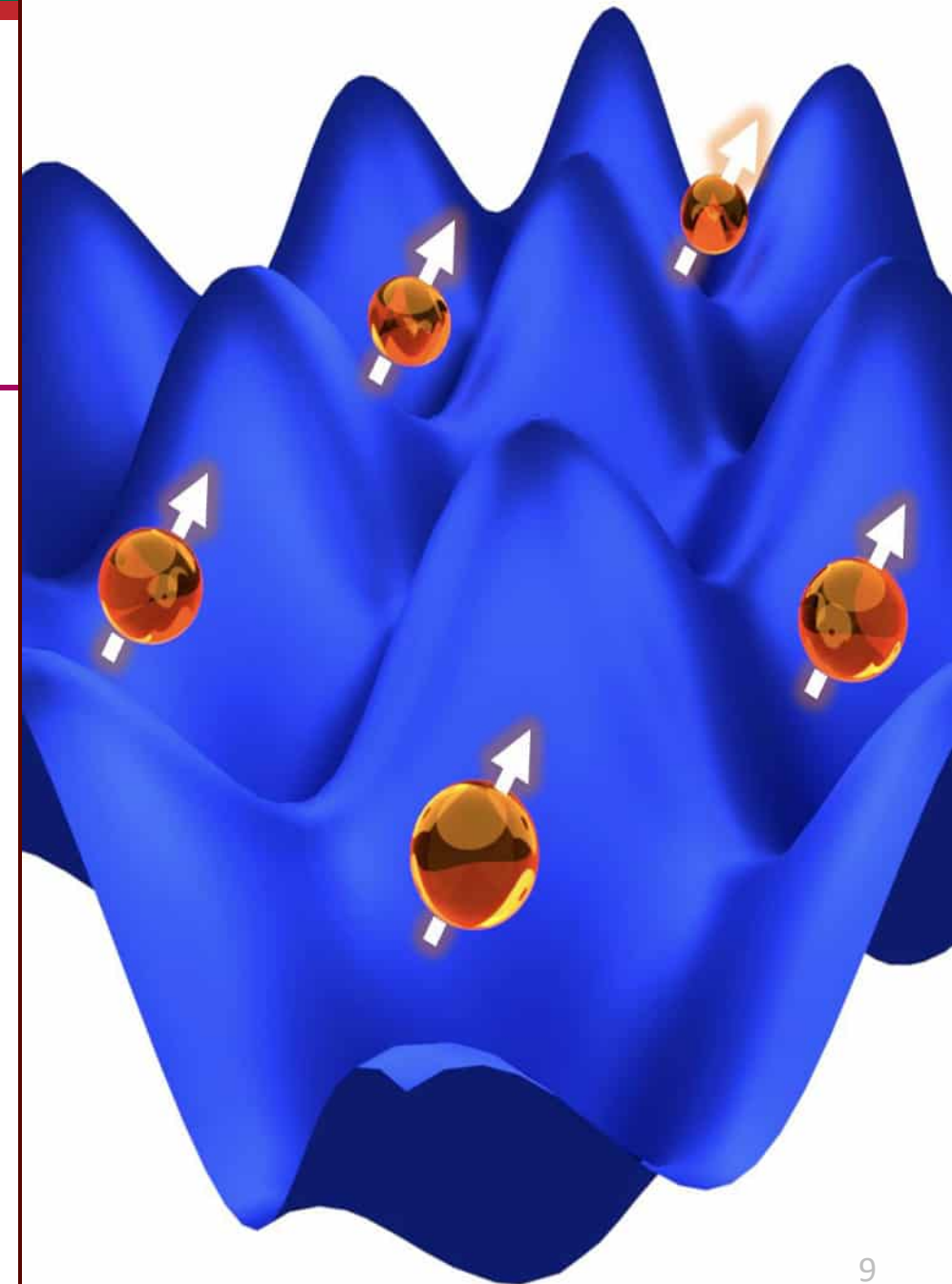# Quantum technology-related research activities in Lithuania

Theory groups
- Cold atoms and Quantum Optics Theory Group
- Open Quantum Systems Theory Group
- Electronic Structure Theory Group

Experiment
- Spin-based QT research
- Quantum Communication
- Quantum Communication in Space
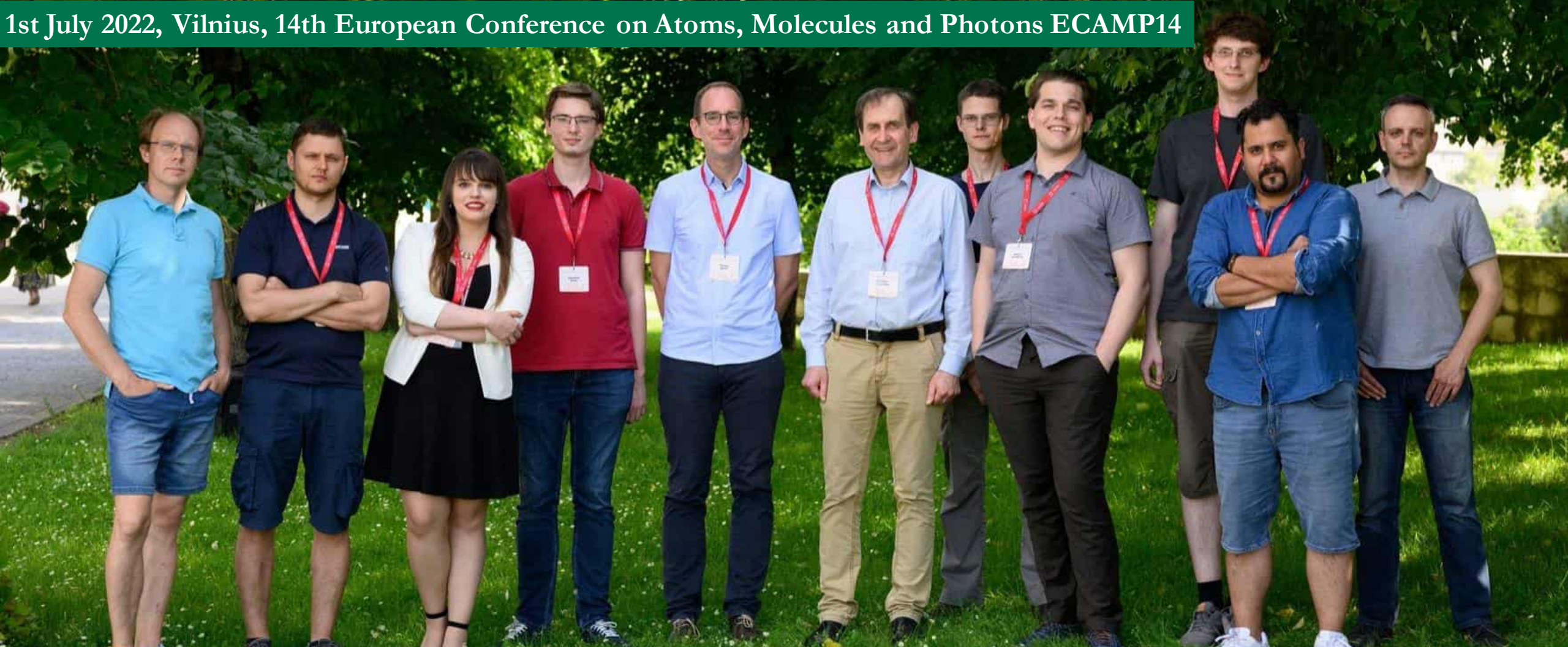- Quantum Materials

Business
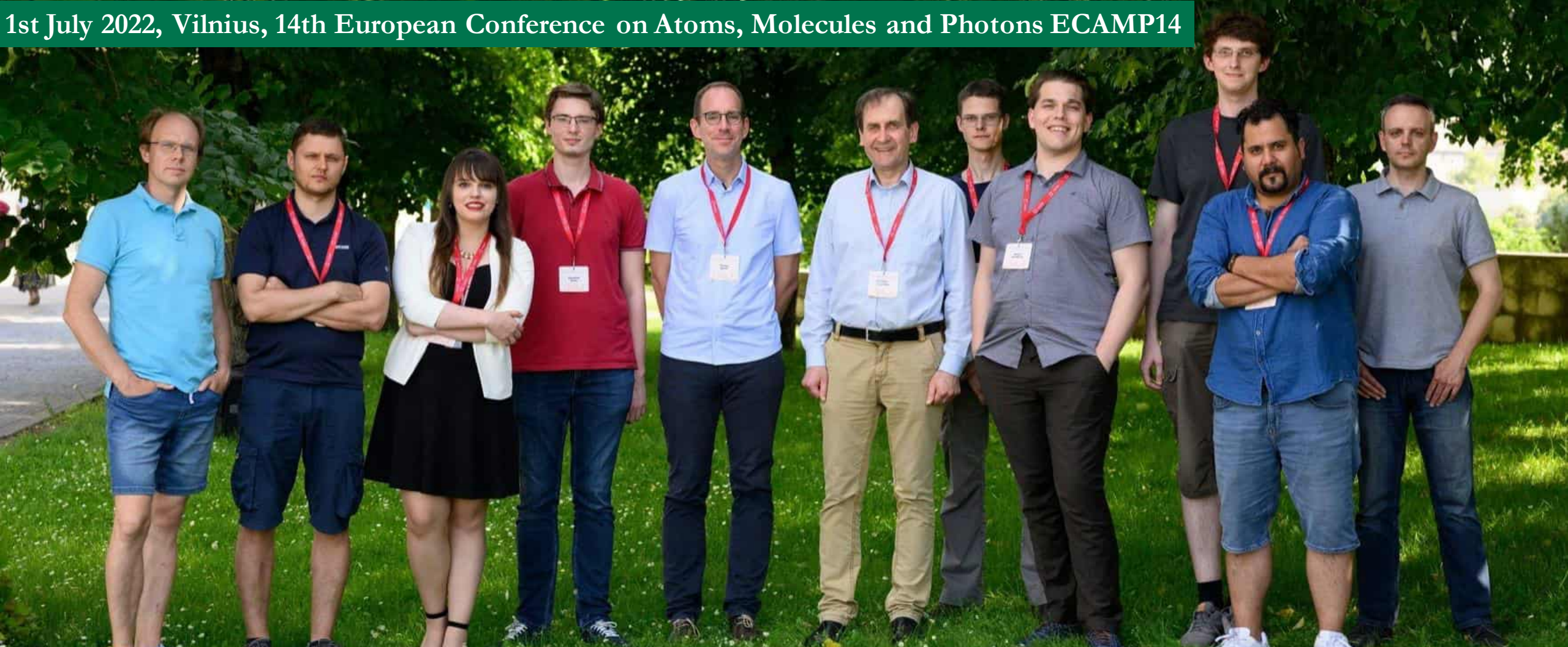- Novian Technologies' High-Performance Computing Expertise

E. Anisimovas, V. Novičenko, M. Mackoit-Sinkevičienė, D. Burba, T. Busch (Univ. Okinawa, Japan), G. Juzeliūnas, M. Račiūnas, E. Gvozdiovas, G. Žlabys, H. R. Hamedi, V. Kudriašov
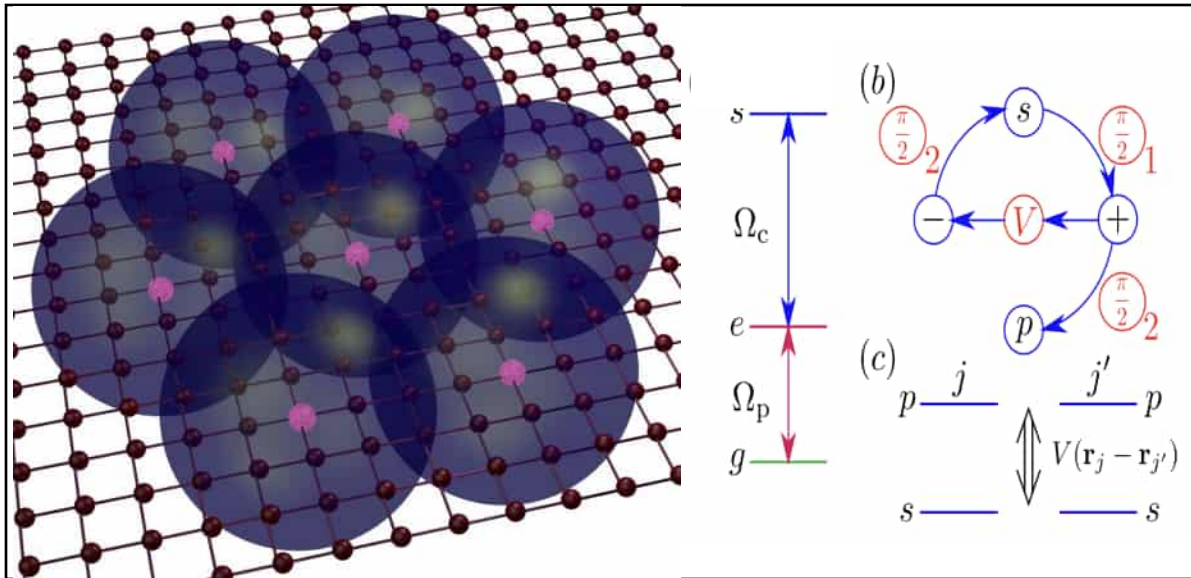
E. Anisimovas, V. Novičenko, M. Mackoit-Sinkevičienė, D. Burba, T. Busch (Univ. Okinawa, Japan), G. Juzeliūnas, M. Račiūnas, E. Gvozdiovas, G. Žlabys, H. R. Hamedi, V. Kudriašov
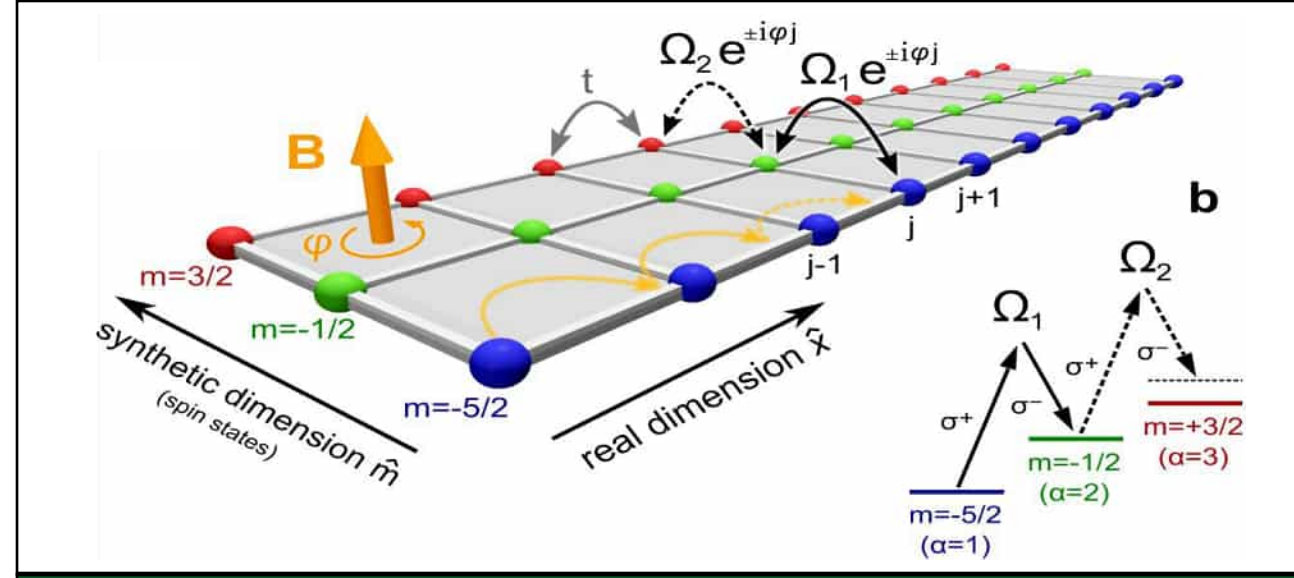
New Method to provide an efficient way for the operation of Qubits
Vilnius-Taiwan Collaboration

Semi-synthetic optical lattice
Vilnius-USA Collaboration

Quantum Simulations using ultracold atoms

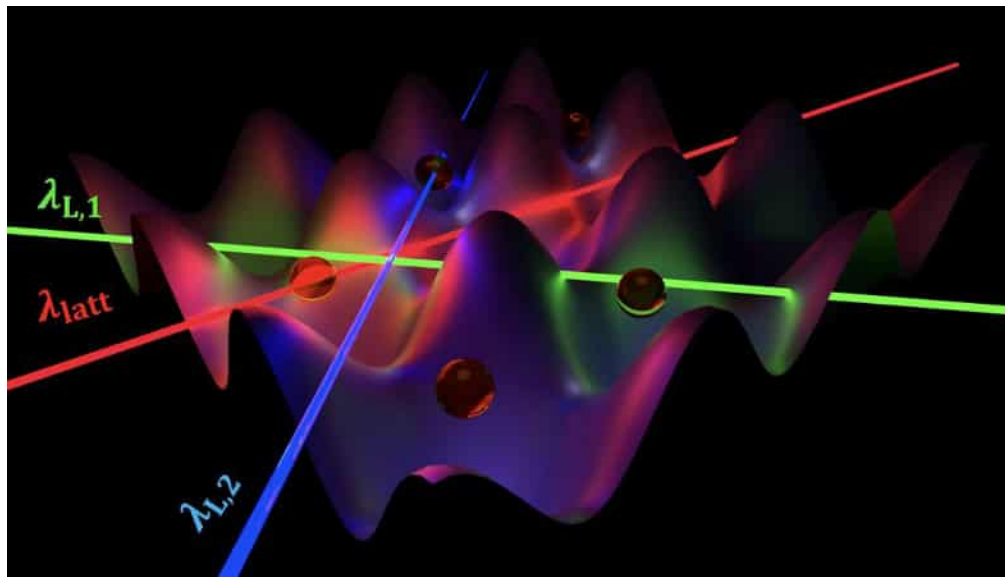www.quantum.tfai.vu.lt , gediminas.juzeliunas@tfai.vu.lt

Cold Atoms and Quantum Optics group
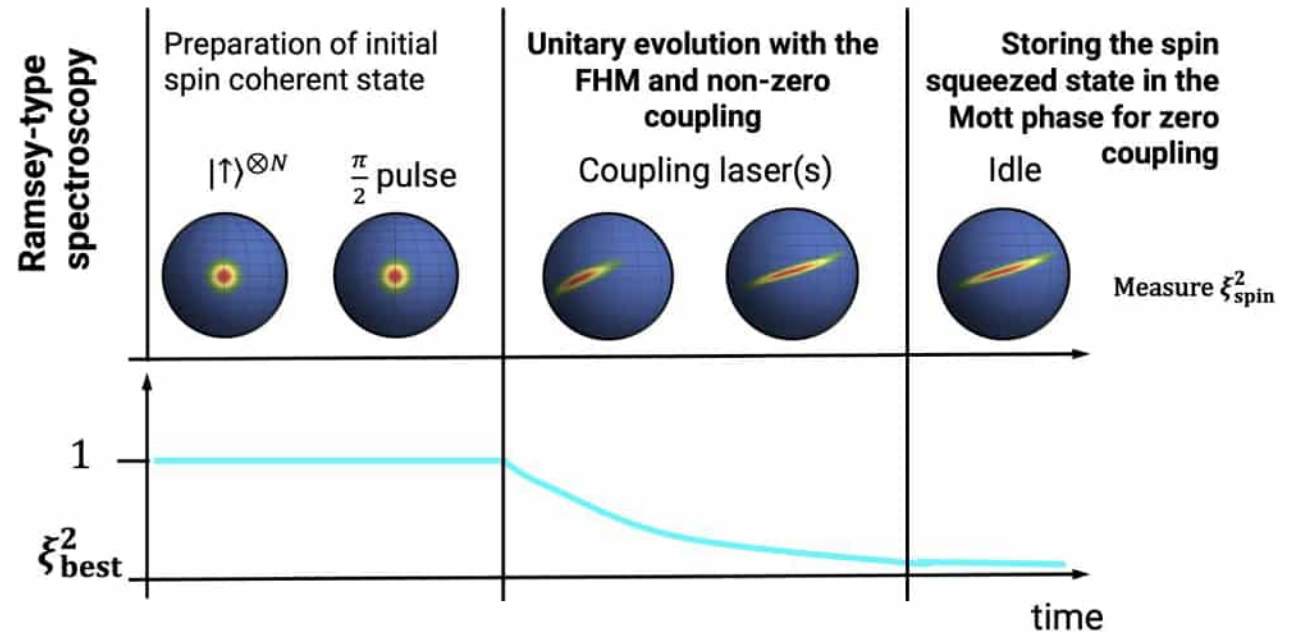
Prof. Gediminas Juzeliūnas

Quantum Metrology

New ways to entangle and squeeze atomic spin states

Used to enlarge the sensitivity of atomic clocks through quantum correlations.
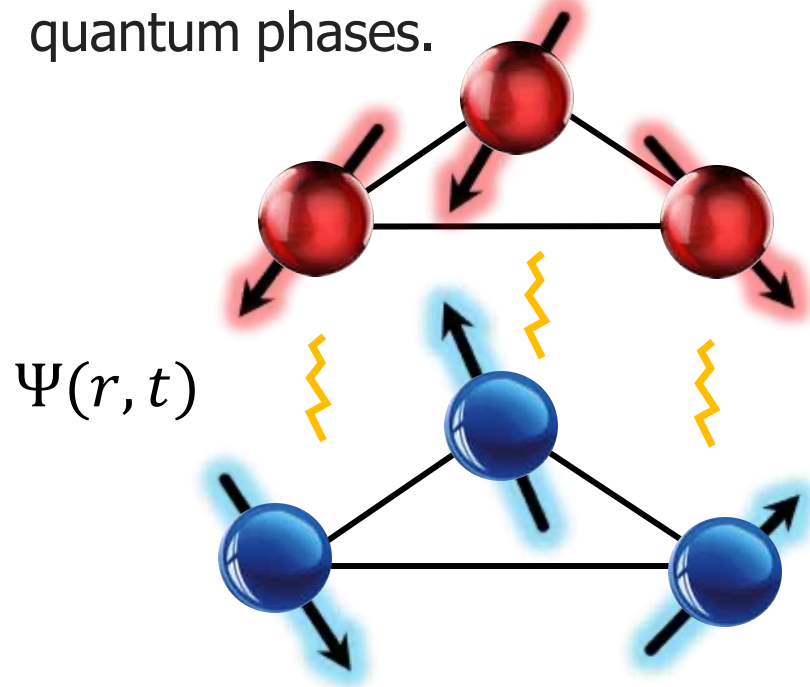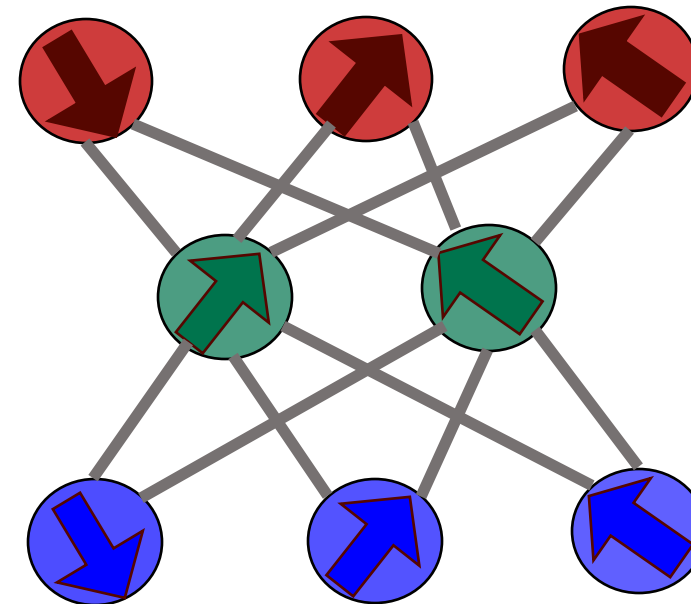
Vilnius-Warsaw Collaboration

Machine Learning – neural network quantum

- Exploring various neural-network architectures (CNN, RNN, Transformer) to represent quantum complexity.
- Ability to model long-range correlations, encode local and global structures, describe diverse quantum phases.

$\Psi(r,t)$

Approximation

Quantum State

Neural Network for the Quantum State

14

Cold Atoms and Quantum Optics group

Prof. Gediminas Juzeliūnas

3 BIG SCALE EU PROJECTS ON QUANT. TECHNOLOG.

- ES FP7 STREP project NAMEQUAM "**Nanodesigning of Atomic and Molecular Quantum Matter**" (2010-2012). Project leader of the Lithuanian side – Gediminas Juzeliūnas.

- ES FP7 IRSES project COLIMA - **Coherent Manipulation of Light and Matter via Interferences of Laser-Dressed States**" (2011-2015). Project leader of the Lithuanian side – Gediminas Juzeliūnas.

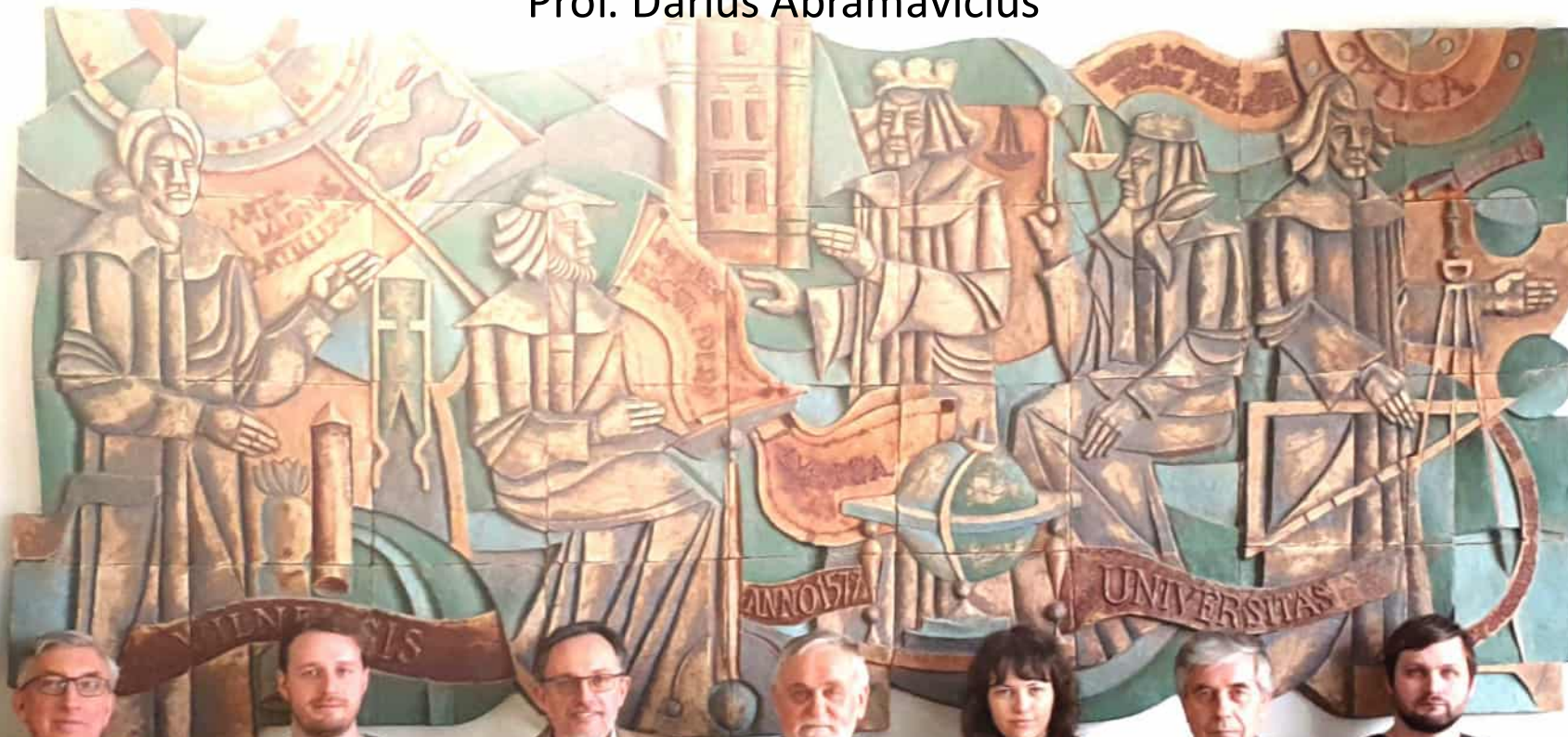   **European Cooperation in Science and Technology**

- COST action CA16221 project "**Quantum Technologies with Ultra-Cold Atoms**" (AtomQTech) (2017-2021). Project Coordinator in Lithuania – Gediminas Juzeliūnas.

www.quantum.tfai.vu.lt   ,   gediminas.juzeliunas@tfai.vu.lt
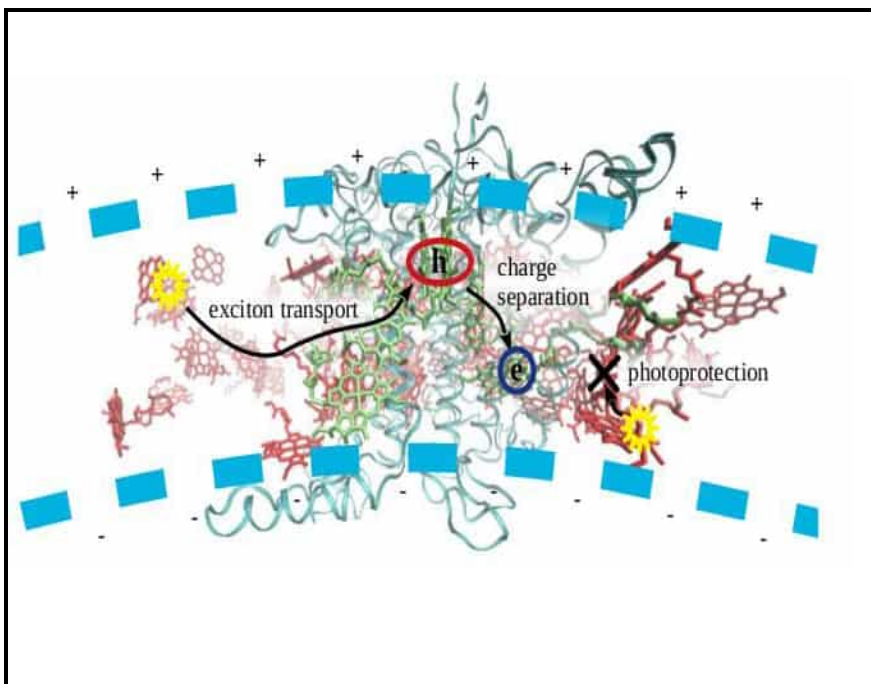
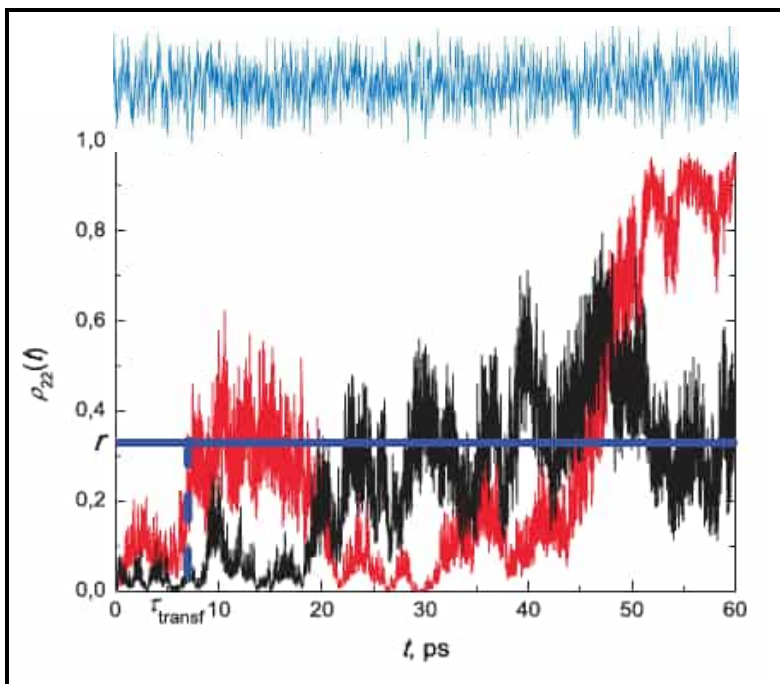# Open Quantum Systems group

Prof. Darius Abramavičius
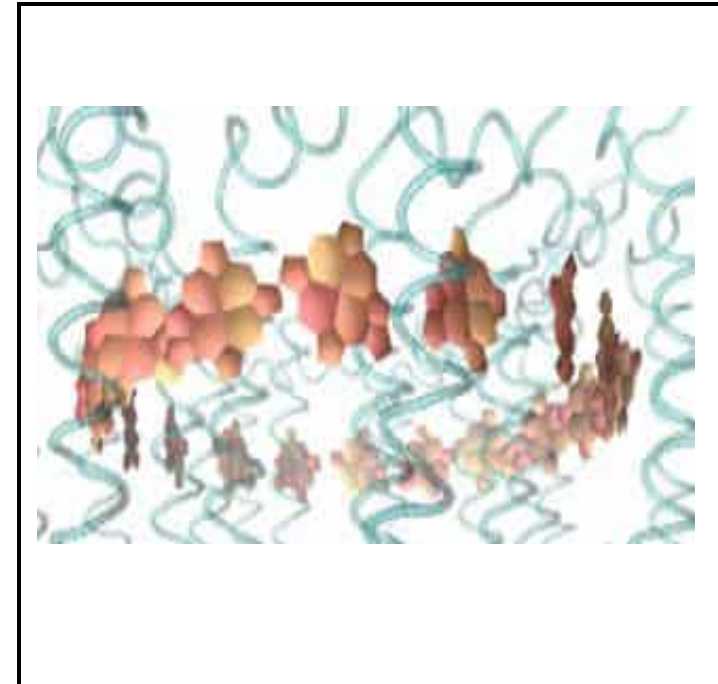
Open Quantum Systems group

Prof. Darius Abramavičius

Self-organized quantum "devices" in Nature

Nonlinear spectroscopy

Vilnius-USA-France

Stochastic quantum trajectories

Vilnius-Czech

Quantum entanglement among molecules

Vilnius-Germany
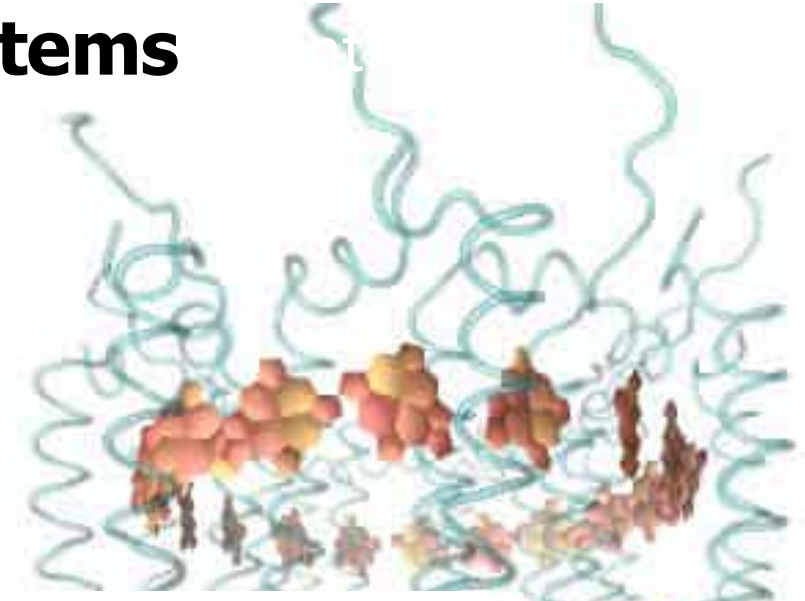
darius.abramavicius@ff.vu.lt

Multi-dimensional laser spectroscopy to follow quantum dynamics in model systems
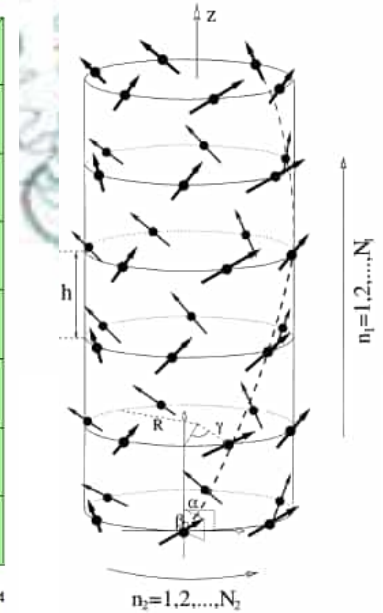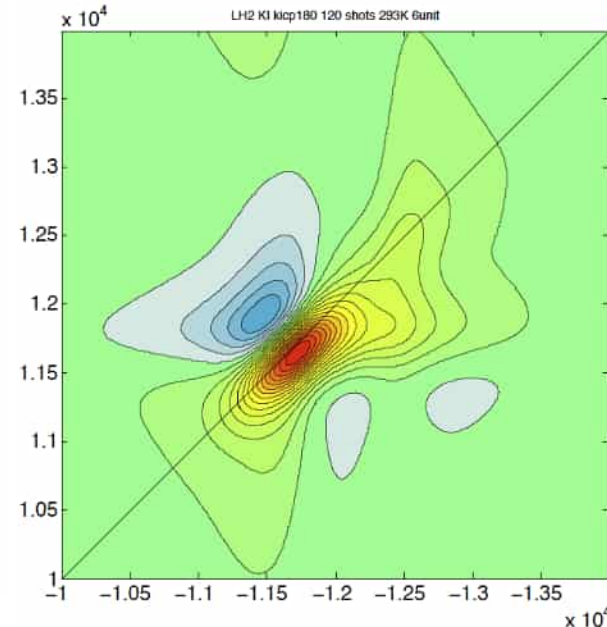
Prof. Darius Abramavičius

- Frequency domain techniques
- 2-nd order nonlinear techniques
- SHG, SFG, DFG

QCFP
Quantum **C**orrelation **F**unctions and **P**ropagators combine coherent and stochastic propagation approaches

Four wave mixing:
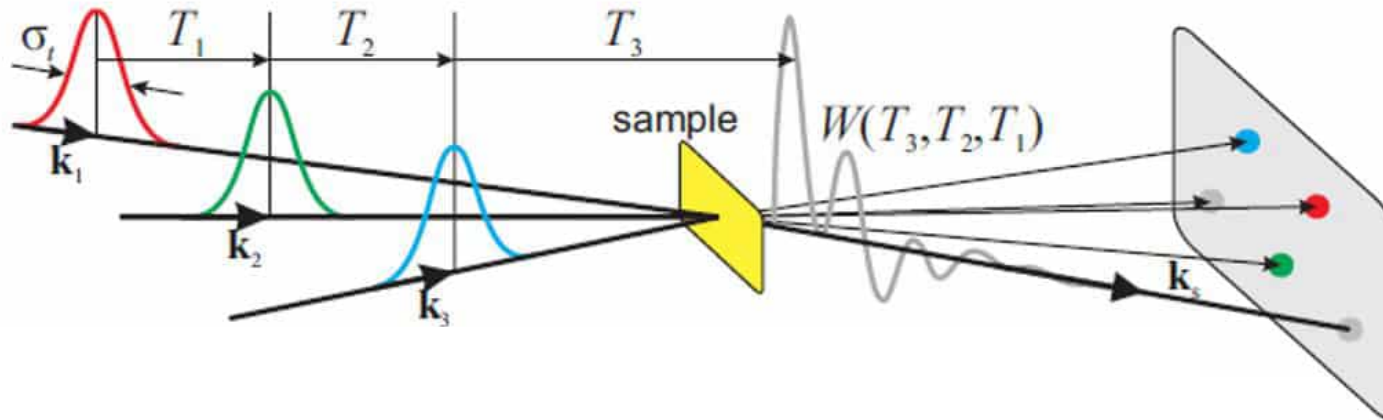
darius.abramavicius@ff.vu.lt

Electronic Structure Theory Group

Prof. Audrius Alkauskas

audrius.alkauskas@ftmc.lt

Electronic Structure Theory Group

prof. Audrius Alkauskas

Theory of point defects for quantum information processing

Funded projects:

M-ERA.NET project MyND (2015-2018).
Quantum Flagship Project Asteriqs (2018-2021)

Collaboration with
Australia, USA, Norway, Hungary

audrius.alkauskas@ftmc.lt
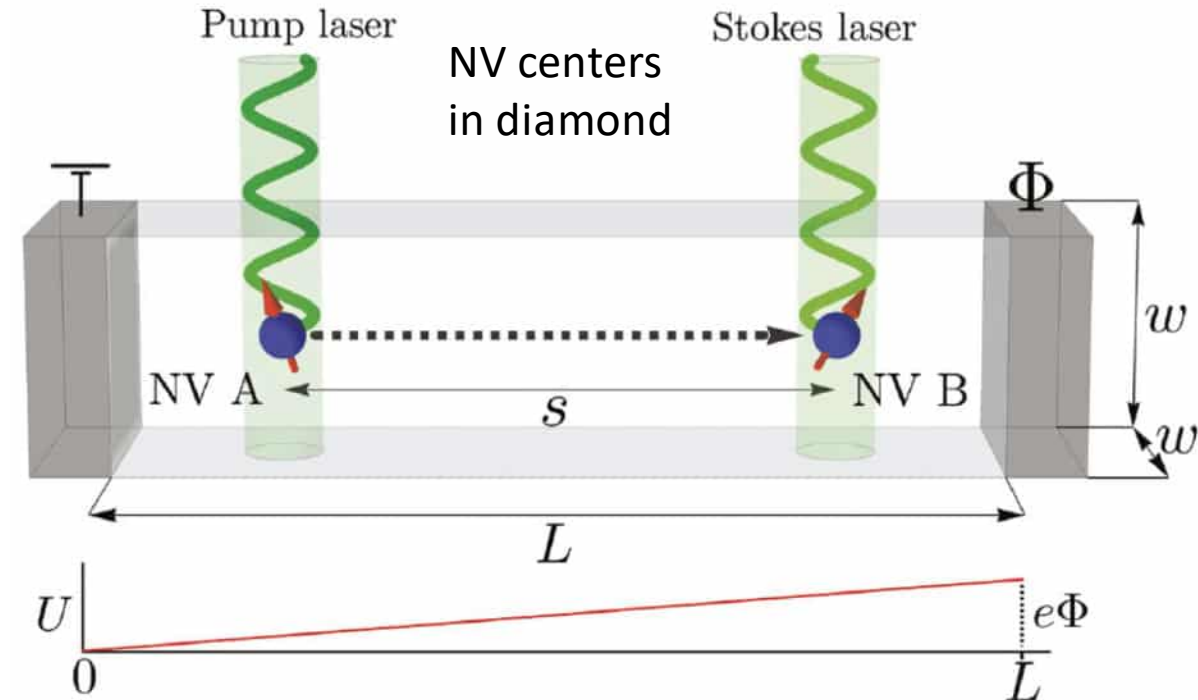
Computational resources   Prof. Juozas Šulskus

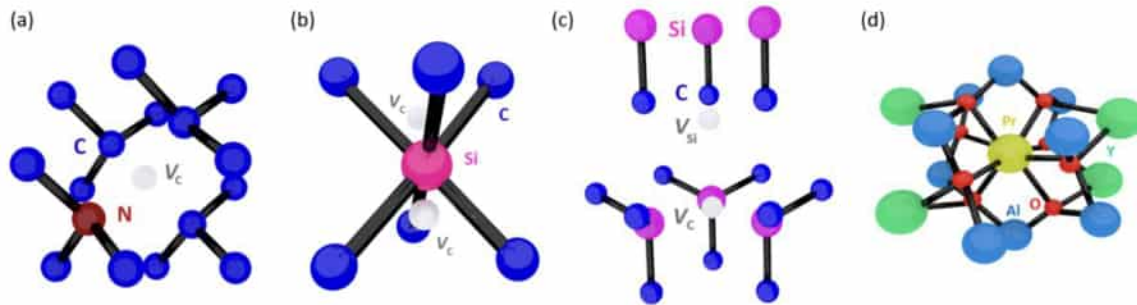VU Faculty of Physics, Vilnius, Lithuania

„**HPC Sauletekis**" - Full member of Europe Grid Infrastructure

VU – leading national HPC Competence Center (part of EuroHPC Competence Center)

Quantum Computer Simulations

Supercomputer „VU HPC" Saulėtekis

VU Physics Faculty
National Center for Physical Sciences and Technology

0.31 PFlops homogeneous hardware
HPLinpack: R=0.25 Pflops

juozas.sulskus@ff.vu.lt , mindaugas.macernis@ff.vu.lt
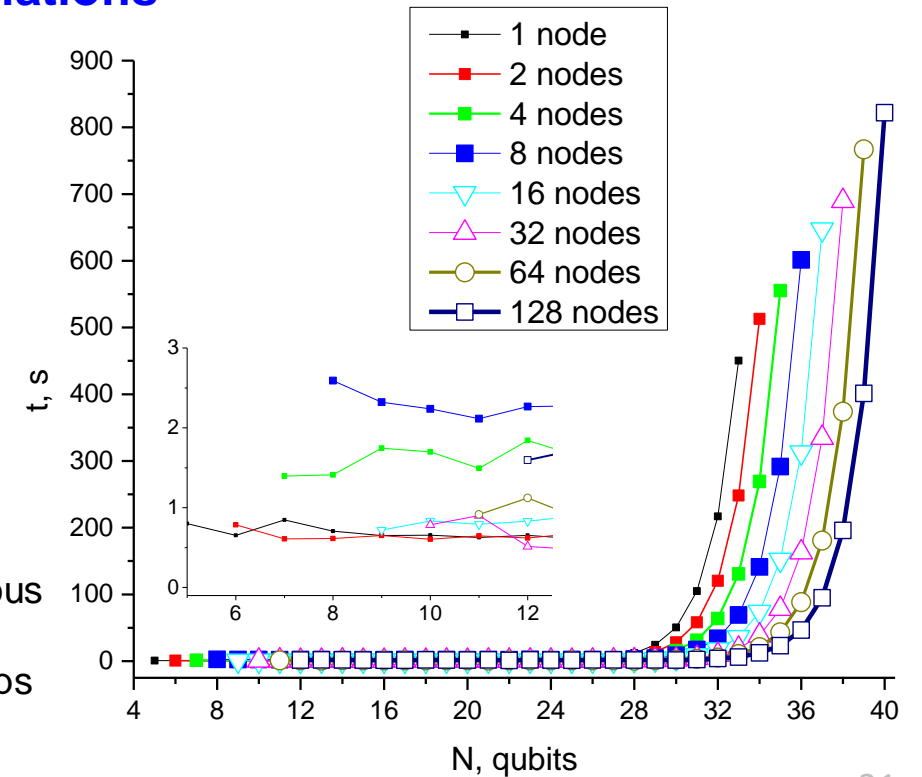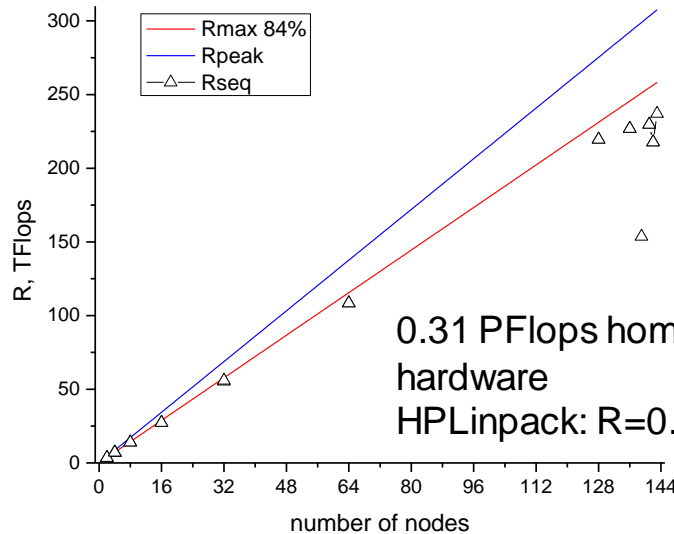
Spin-based QT experimental research
Dr. Mantas Šimėnas
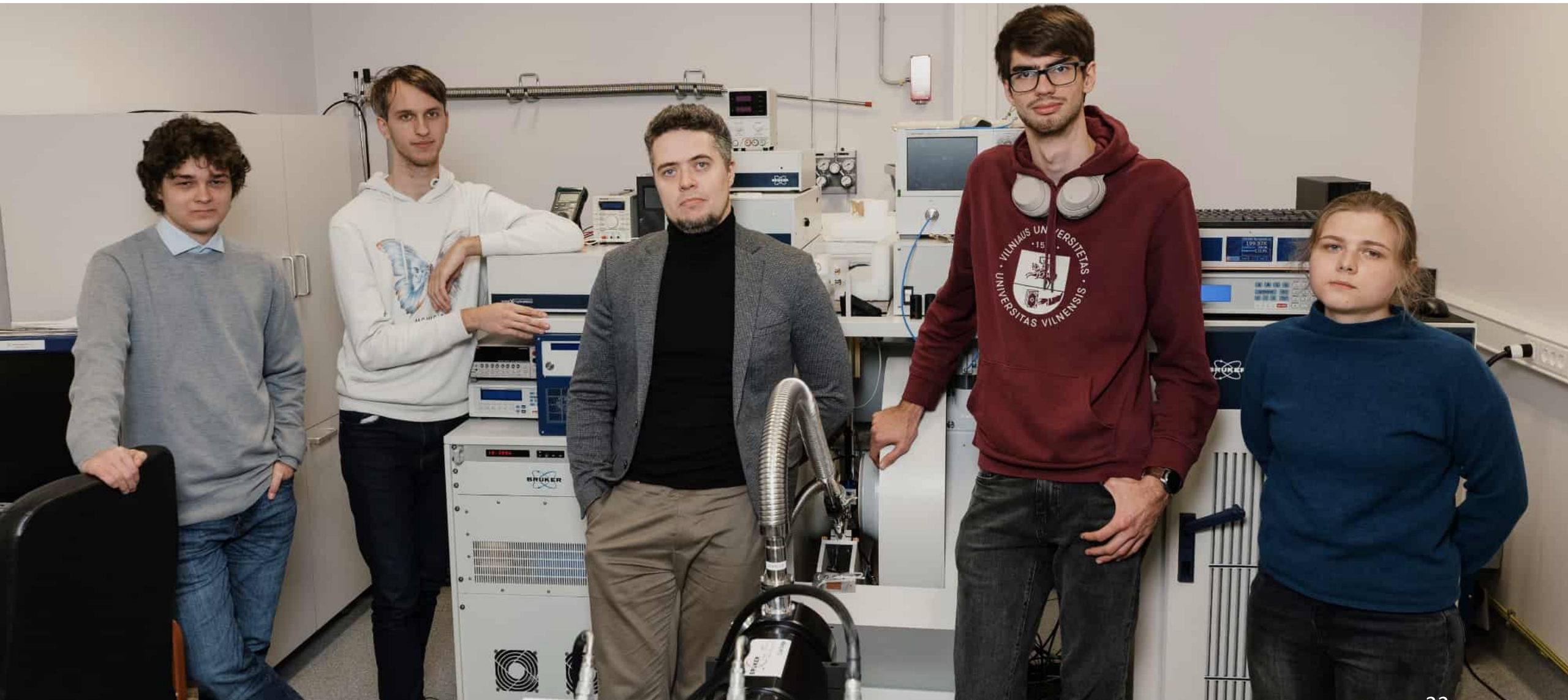
Spin-based QT experimental research
Dr. Mantas Šimėnas

Collaboration with **UCL**

- **Investigation of materials for spin-based QT**

Implanted $^{125}Te^+$ spins in Si at a depth of 20 nm. Record coherence time for near-surface spins
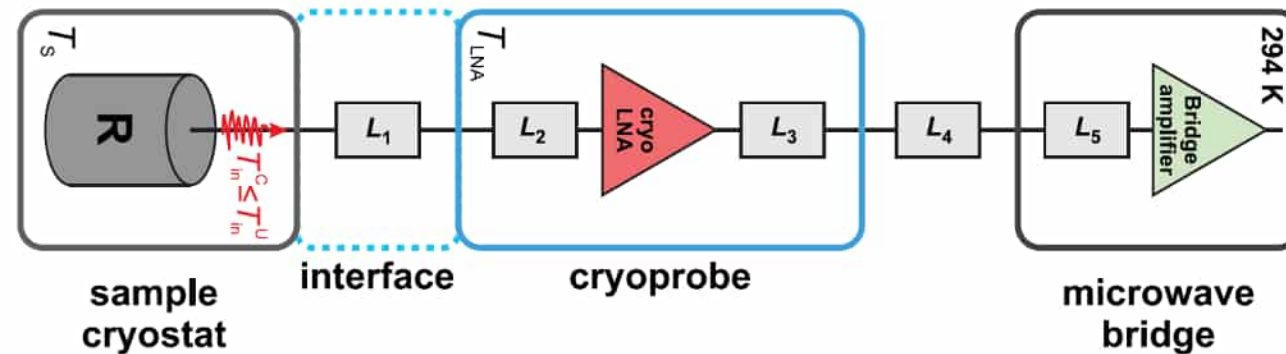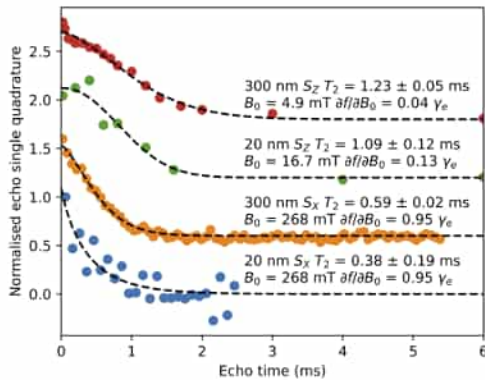
Electron spin resonance cryoprobe with a HEMT – ESR enabling technology
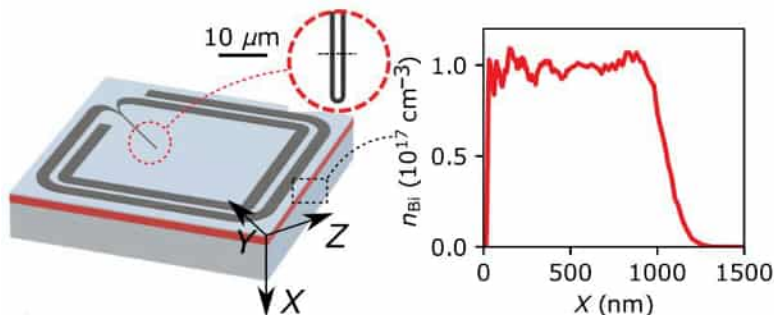
Coupling of superconducting microresonators to spin ensembles in Silicon and YSO
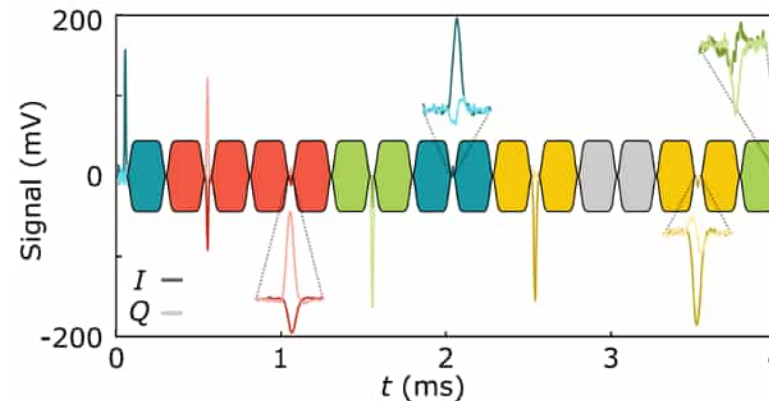
Implementation of random-access spin-based quantum memory using chirped microwave pulses

mantas.simenas@ff.vu.lt

23

Quantum Optics group at Laser Research Center

Dr. Vygandas Jarutis

VU Faculty of Physics
Laser Research Center

Femtosecond oscillator „Flint" (*Light Conversion*) and time-correlated single-photon counting module „PicoHarp 300 (*PicoQuant*) used in quantum optics experiments.

Research topics

- Quantum interference effects
- Triple photon generation research
- Squeezed light sources

Location: VU / Faculty of Physics, Vilnius, Lithuania
Access: Laser Research Center
Management: Laboratory of Quantum Optics

vygandas.jarutis@ff.vu.lt

Department of Optoelectronics

Dr. Tadas Paulauskas

Quantum Materials
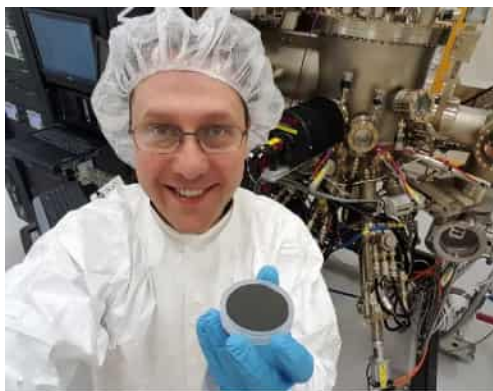
Collaborations

University of Illinois at Chicago
Argonne National Laboratory
Lawrence Berkeley National Laboratory
Aalto University

University of Paris-Saclay
Polish Academy of Sciences
Swinburne University of Technology
KTH Royal Institute of Technology

tadas.paulauskas@ftmc.lt

Advanced synthesis of materials and devices

Dr. Tadas Paulauskas

Molecular beam epitaxy of III-V materials

- Quantum wells and quantum dots

- Quantum cascade lasers

- 2D bismuth-based materials

- Metamorphic and strained epitaxy

- Thin film devices, integration with Si
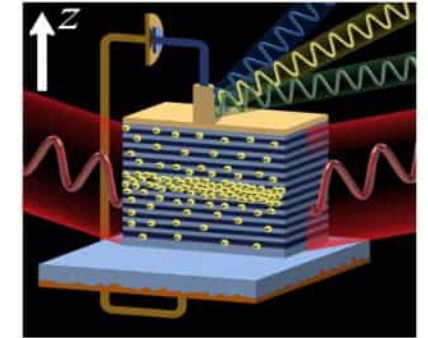
Parametric grain in GaAs/AlGaAs superlattices

Device prototyping and fabrication

- ISO7 - ISO5 clean rooms

- Laser and e-beam litography

- Dry / wet etching

- ALD, PECVD

From atomic-structure to full device characterization

Bi-M   1 nm

tadas.paulauskas@ftmc.lt

Department of Laser Technologies

Dr. Vidmantas Tomkus, Lithuanian Space Association
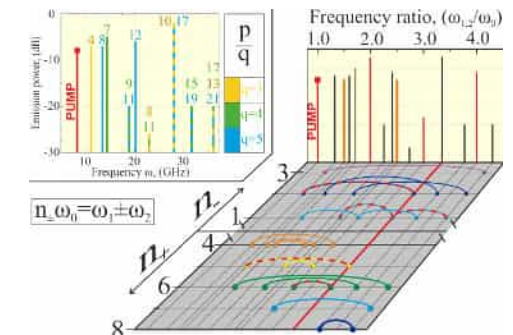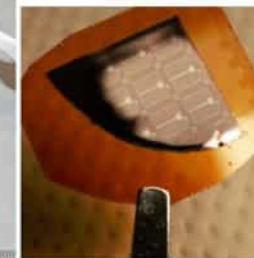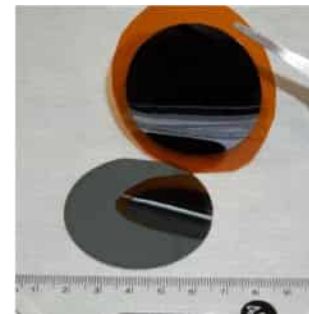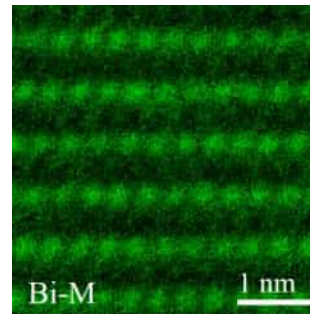
Fiber-based Source of Entangled Photon Pairs for Satellite Quantum Communications
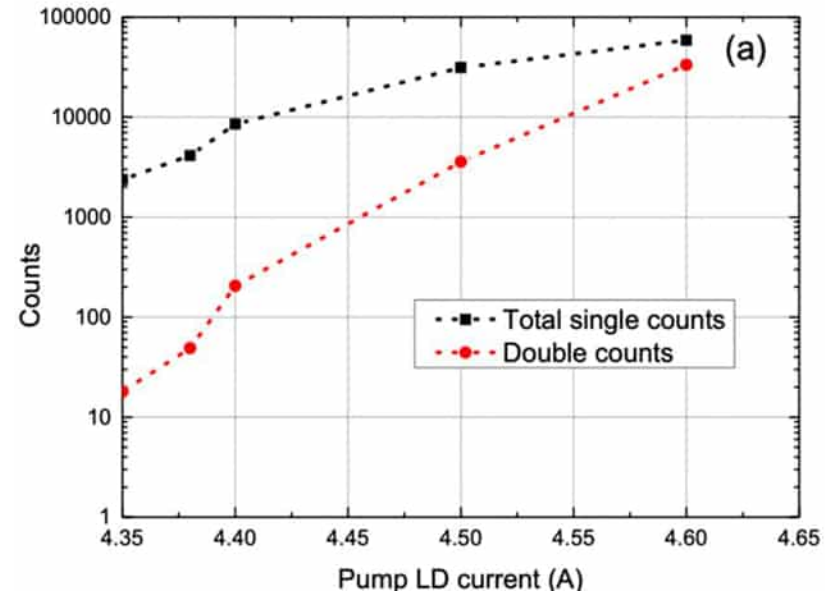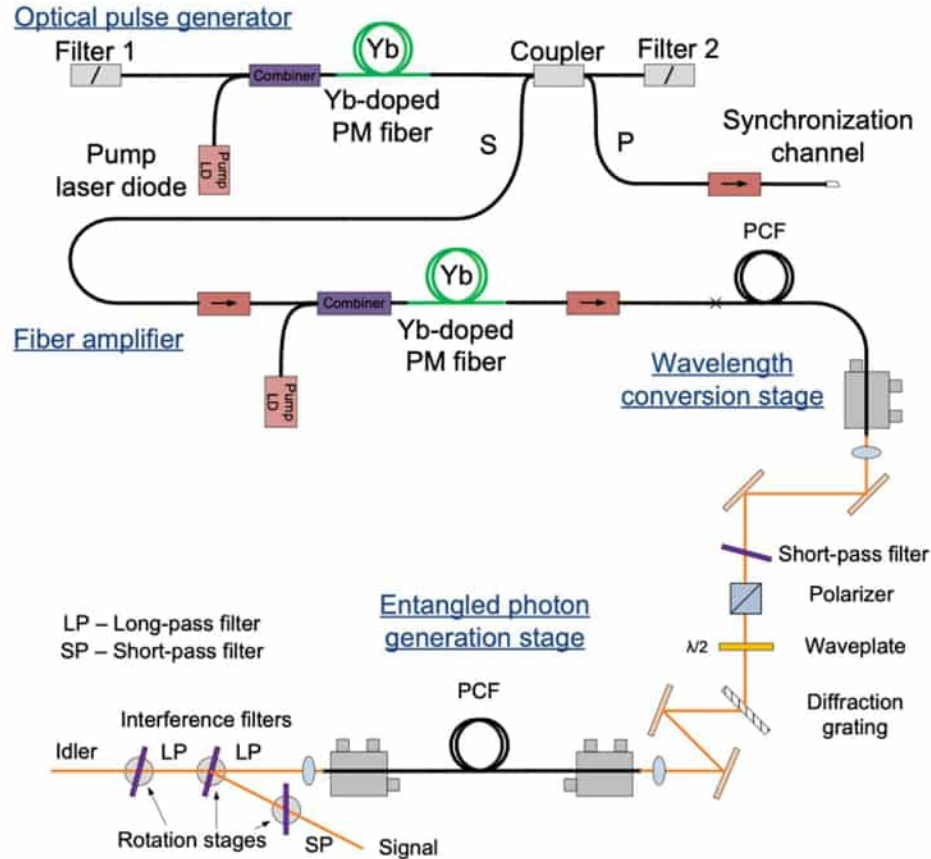
Diagram of the entangled photons source

vidmantas.tomkus@ftmc.lt

Novian Technologies

CEO Gytis Umantas

Novian Technologies is a highly professional and experienced company in Lithuania that implements **complex HPC solutions worldwide**. Today, 25 countries on 3 continents are using their HPC solutions (including leading Vilnius University) for climate change, weather forecasting and other scientific and business purposes.

The majority of **currently implemented solutions are based on classic CPU/GPU architecture and can run Quantum simulations**. If you are interested in learning more about their cutting-edge technologies, we have a Novian Technologies representative in our delegation.

g.umantas@novian.lt

Novian Technologies

CEO Gytis Umantas

Novian Technologies is a highly professional and experienced company in Lithuania that implements **complex HPC solutions worldwide**. Today, 25 countries on 3 continents are using their <u>HPC solutions (including leading Vilnius University) for climate change, weather forecasting and other scientific and business purposes</u>.

The majority of **currently implemented solutions are based on classic CPU/GPU architecture and can run Quantum simulations**. If you are interested in learning more about their cutting-edge technologies, we have a Novian Technologies representative in our delegation.

Projects

- **Vilnius University** (VU) Faculty of Mathematics and Informatics: installation of HPC cluster
- **8 West African countries**: HPC implementation for climate change monitoring for WASCAL (West African Science Service Centre on Climate Change and Adapted Land Use)
- **Bangladesh Meteorology Department**: HPC solution for climate change monitoring, weather forecasting, early warning system
- **16 South African countries**: HPC implementation for SADC (Southern African Development Community) meteorological departments (Phase I and Phase II)

g.umantas@novian.lt

29

The Lithuanian National Quantum Technology Program (in progress)

The Lithuanian Parlament Comission has initiated such a programme

Strengthening collaboration with the Northern countries

Potential collaboration areas

- spin squeezing and atomic clocks (Sr), atomic ensembles

- quantum simulations, spin excitations in spin chains

- stochastic quantum dynamics/decoherence

- machine learning, big data, processing

- colour centres in diamond, atomic physics

- spin qubits in GaAs/AlGaAs quantum dots

- single and entangled photon sources in III-V materials

- spin ensembles
- & more …

Strengthening collaboration with the Northern countries

Potential collaboration areas

- spin squeezing and atomic clocks (Sr), atomic ensembles

- quantum simulations, spin excitations in spin chains

- stochastic quantum dynamics/decoherence

- machine learning, big data, processing

- colour centres in diamond, atomic physics

- spin qubits in GaAs/AlGaAs quantum dots

- single and entangled photon sources in III-V materials

- spin ensembles
- <u>& more</u> …